U.S. DEPARTMENT OF COMMERCE
National Technical Information Service
PB-272 253

Grand Lake and Shadow Mountain Lake, Grand County, Colorado

National Eutrophication Survey, Corvallis, Oreg.

Prepared for
Corvallis Environmental Research Lab, Oreg.

Jul 77

PB 272 233

U.S. ENVIRONMENTAL PROTECTION AGENCY
NATIONAL EUTROPHICATION SURVEY

WORKING PAPER SERIES

CORVALLIS ENVIRONMENTAL RESEARCH LABORATORY - CORVALLIS, OREGON
and
ENVIRONMENTAL MONITORING & SUPPORT LABORATORY - LAS VEGAS, NEVADA

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U. S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

U.S.G.P.O. 699-440

Report
on
Grand Lake and Shadow Mountain Lake
Grand County
Colorado
EPA Region VIII
Working Paper No. 770

With the cooperation of the
Colorado Department of Health
and the
Colorado National Guard
July, 1977

PB272233

Report on Grand Lake and Shadow Mountain Lake, Grand County, Colorado

Prepared July 1977

Author(s) [National Eutrophication Survey Staff]

Performing Organization Name and Address
National Eutrophication Survey
U.S. Environmental Protection Agency
200 S. W. 35th St.
Corvallis, Oregon 97330

Working Paper # 770

Sponsoring Organization Name and Address
Office of Research and Development
U.S. Environmental Protection Agency
401 M Street, S. W.
Washington, DC 20460

Final - 1975

Supplementary Notes
Prepared in cooperation with the U.S. Environmental Protection Agency, National Environmental Research Center, Las Vegas, Nevada 89114

Average total phosphorus and total nitrogen loadings to the lake were estimated and quantified according to either point or non-point source origin. An assessment of the lake's current condition and trophic potential is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

Key Words and Document Analysis
Descriptors
eutrophication
lakes
nutrients
phosphorus
nitrogen
loading

Identifiers/Open-Ended Terms

Availability Statement
Release unlimited

Security Class (This Report) UNCLASSIFIED
Security Class (This Page) UNCLASSIFIED

COSATI Field/Group 08H
08C

No. of Pages 52
Price PC A04 / MF A01

CONTENTS

	Page
Foreward	ii
List of Colorado Study Lakes and Reservoirs	iv
Lake and Drainage Area Map	v
Sections	
I. Conclusions	1
II. Lake and Drainage Basin Characteristics	4
III. Lake Water Quality Summary	6
IV. Nutrient Loadings	12
V. Literature Reviewed	17
VI. Appendices	18

FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nation-wide threat of accelerated eutrophication to freshwater lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGEMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the Colorado Department of Health for professional involvement, to the Colorado National Guard for conducting the tributary sampling phase of the Survey, and to those wastewater treatment plant operators who voluntarily provided effluent samples.

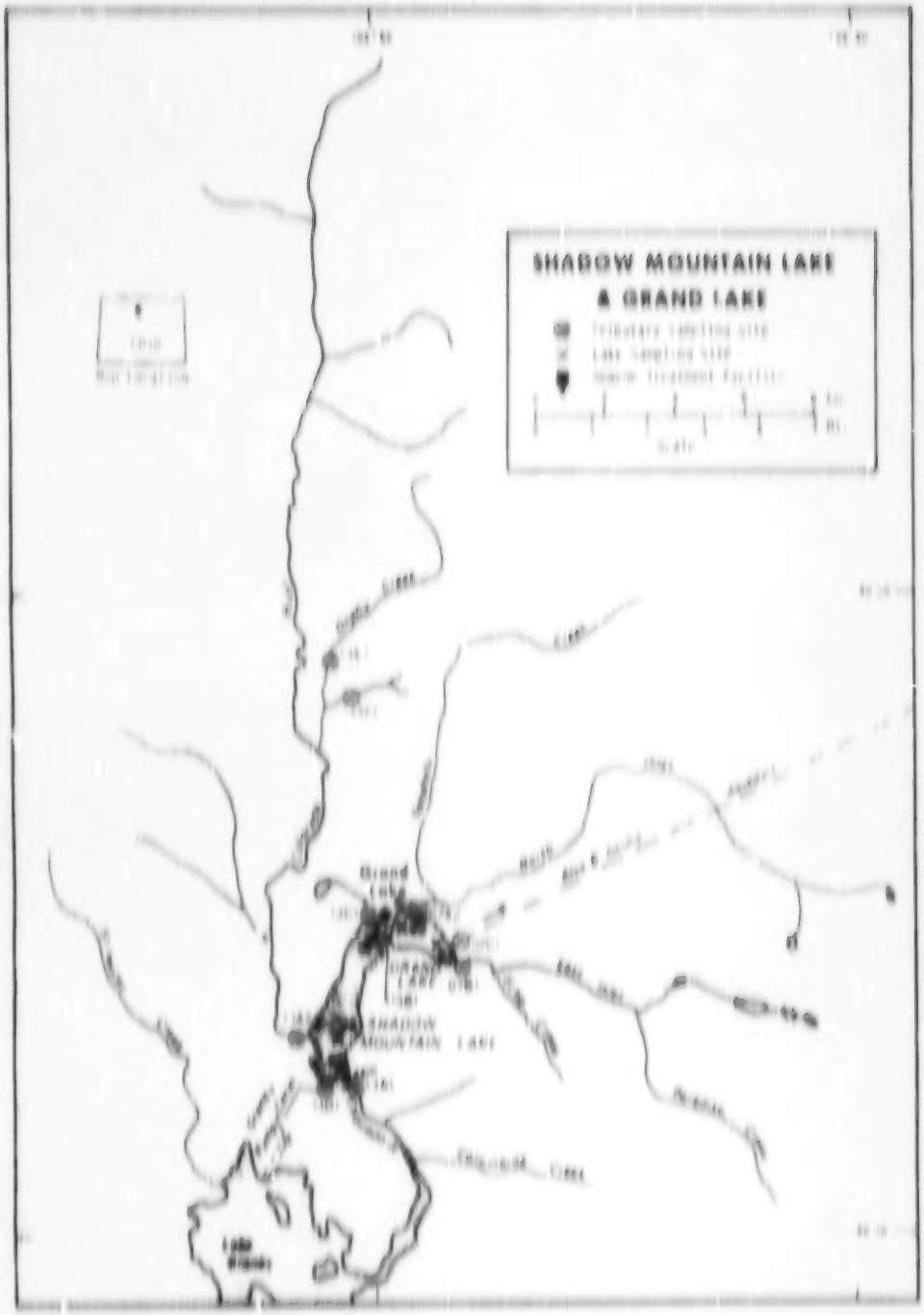
The staff of the Water Quality Control Division provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports, and provided critiques most useful in the preparation of this Working Paper series.

Lt. Colonel Paul A. Parsons, the Deputy Adjutant General of Colorado, and Project Officer Colonel Hershel C. Yeargan, who directed the volunteer efforts of the Colorado National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

NATIONAL EUTROPHICATION SURVEY
STUDY LAKES AND RESERVOIRS

STATE OF COLORADO

NAME	COUNTY
Barker	Boulder
Barr	Adams
Blue Mesa	Boulder
Cherry Creek	Arapahoe
Cucharas	Huerfano
Dillon	Summit
Grand	Grand
Green Mountain	Summit
Holbrook	Otero
Meredith	Crowley
Milton	Weld
Navajo	Archuleta, CO; San Juan, Rio Arriba, NM
Shadow Mountain	Grand


SHADOW MOUNTAIN LAKE
& GRAND LAKE
SHADOW
MOUNTAIN LAKE

GRAND LAKE AND SHADOW MOUNTAIN LAKE
STORET NOS. 0807 and 0813

I. CONCLUSIONS

A. Trophic Condition:

Survey data indicate that Grand Lake and Shadow Mountain Lake are mesotrophic. Of the 13 Colorado lakes and reservoirs sampled in 1975, Grand Lake ranked third and Shadow Mountain Lake ranked fourth in overall trophic quality when compared using a combination of six water quality parameters*.

1. Grand Lake--Two of the waterbodies had less median total phosphorus, two had less and one had the same median dissolved orthophosphorus, none had less and six had the same median inorganic nitrogen, two had less mean chlorophyll a, and one had greater mean Secchi disc transparency. Some depression of dissolved oxygen with depth (to 4.8 mg/l at 6.1 meters) occurred at station 1 in August.

Survey limnologists did not observe nuisance aquatic growths during their visits.

In a previous report it is noted that Grand Lake acts as a sink for materials sedimenting out of natural inflows and pumped inflows from Shadow Mountain Lake; and, as a consequence, inflow-outflow conditions make the characteristics of the upper 5 to 10 meters of the lake quite similar to those of Shadow Mountain Lake (Nelson, 1971).

* See Appendix A.

2. Shadow Mountain Lake--four of the waterbodies had less median total phosphorus; two had less and one had the same median dissolved orthophosphorus, none had less and six had the same median inorganic nitrogen, four had less mean chlorophyll a; and five had greater mean Secchi disc transparency. No dissolved oxygen depression occurred during the sampling. Survey limnologists did not observe any nuisance conditions.

Shadow Mountain Lake, due to its hydrology and morphometry, has been regarded as a reversible flow-through system. At certain times in the year, it receives nutrients primarily from secondarily-enriched water pumped from Lake Granby; and aquatic plants are abundant at times (Nelson, op. cit.).

Although neither lake is presently considered to be eutrophic, it has been concluded that orthophosphorus concentrations are close to or exceed the minimum levels necessary to support algal blooms, and that the inflow from Shadow Mountain Lake may be primarily responsible for the enrichment of Grand Lake (Nelson, op. cit.).

B. Rate-Limiting Nutrient:

The algal assay results indicate that Grand Lake was phosphorus limited at the times the samples were collected (08/26/75 and 10/10/75). The lake data indicate phosphorus limitation at both sampling stations and times.

The results of the algal assays for Shadow Mountain Lake are not considered representative of conditions in the lake at the sampling times due to a significant change in nutrients in the

samples during shipment from the field to the laboratory. The lake data indicate phosphorus limitation at station 1 in August and at station 3 in August and October. Nitrogen limitation is indicated at all other sampling stations and times.

C. Nutrient Controllability:

1. Point sources--During the sampling year, point sources accounted for 9.2% of the total phosphorus load to Grand and Shadow Mountain lakes. The Grand Lake Sanitation District wastewater treatment plant contributed 8.8%, and septic tanks serving lakeshore dwellings contributed an estimated 0.4%. However, since much of the population around the lakes is seasonal, an additional investigation would have to be undertaken to determine the significance of such sources.

The present phosphorus loading of 1.38 g/m^2/year is just a little less than that proposed by Vollenweider (Vollenweider and Dillon, 1974) as a eutrophic loading (see page 16). In a previous report it is noted that even though the lakes are not presently considered eutrophic, system operations combined with continued sewage input could eventually result in a eutrophic system (Nelson, op. cit.). The Survey results appear to confirm this conclusion since the loading measured during the sampling year was a borderline eutrophic loading.

2. Non-point sources--Non-point sources accounted for 90.8% of the total phosphorus loading during the sampling year. The Granby Pump Canal contributed 48.7%, the Colorado River contributed 22.7%, the North Inlet contributed 12.1%, and Echo Creek contributed 4.8%. The ungaged minor tributaries and immediate drainage area contributed an estimated 1.3%.

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS[†]

A. Morphometry[††]:

1. Grand Lake:
   a. Surface area: 2.05 kilometers^2.
   b. Mean depth: 41.3 meters.
   c. Maximum depth: 81.0 meters.
   d. Volume: 84,640 x 10^6 m^3.
2. Shadow Mountain Lake:
   a. Surface area: 5.48 kilometers^2.
   b. Mean depth: 3.8 meters.
   c. Maximum depth: 11.0 meters.
   d. Volume: 20,800 x 10^6 m^3.

B. Mean hydraulic retention time of the system: 92 days.

C. Tributary and Outlet:
(See Appendix C for flow data)

1. Tributaries -

Name	Drainage area (km^2)*	Mean Flow (m^3/sec)*
North Inlet	116.9	1.990
Echo Creek	70.4	1.441
Colorado River	264.2	2.600
Granby Pump Canal	-	7.310
Minor tributaries & immediate drainage -	18.1	0.224
totals	471.6	13.465

† Table of metric equivalents-Appendix B.
†† Anderson, 1974.
* For limits of accuracy, see Working Paper No. 175, "...Survey Methods, 1973-1976".

2. Outlet -

Alva B. Adams Aqueduct		8,990
Colorado River	479.1*	4,280
Total	479.1	13,270

D. Precipitation**:

1. Year of sampling: 52.1 centimeters.

2. Mean annual: 42.7 centimeters.

* Includes area of the lakes.
** See Working Paper No. 175.

III. WATER QUALITY SUMMARY

Grand and Shadow Mountain lakes were sampled two times during the open-water season of 1975 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from six or more depths at two stations on Grand Lake and from two or more depths at three stations on Shadow Mountain Lake (see map, page v). During each visit, a single depth-integrated (4.6 m or near bottom to surface) sample was composited from the stations on each lake for phytoplankton identification and enumeration; and during both visits, a single 18.9-liter depth-integrated sample was composited from each lake for algal assays. Also each time, a depth integrated sample was collected from each of the stations for chlorophyll a analysis. The maximum depths sampled in Grand Lake were 67.1 meters at station 1 and 36.9 meters at station 2. The maximum depths sampled in Shadow Mountain Lake were 1.8 meters at station 1, 3.7 meters at station 2, and 7.3 meters at station 3.

The sampling results are presented in full in Appendix D and are summarized in the following tables.

[illegible]

[illegible]	1ST SAMPLING [illegible]			2ND SAMPLING [illegible]			3RD SAMPLING [illegible]		
	[illegible]			[illegible]			[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[redacted]

PARAMETER	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	3 SITES				3 SITES				3 SITES
TEMP (C)	7.0 - 22.2	15.3	15.5		6.3 - 18.8	9.6	9.8		[redacted]
DISS OXY (MG/L)	6.4 - 7.8	7.2	7.1		5.1 - 8.0	7.2	7.8		[redacted]
[redacted]	23 - 28	24	24		34 - 43	40	41		[redacted]
PH (STAND UNITS)	6.6 - 7.3	6.9	6.8		7.8 - 7.6	7.3	7.3		[redacted]
TOT ALK (MG/L)	23 - 26	24	24		27 - 33	29	29		[redacted]
TOT P (MG/L)	0.020 - 0.075	0.035	0.039		0.020 - 0.059	0.022	0.021		[redacted]
DIFIG P (MG/L)	0.002 - 0.003	0.003	0.003		0.002 - 0.004	0.003	0.003		[redacted]
[redacted]	0.020 - 0.070	0.030	0.030		0.020 - 0.060	0.034	0.025		[redacted]
AMMONIA (MG/L)	0.020 - 0.029	0.025	0.025		0.020 - 0.025	0.020	0.020		[redacted]
K-EL. N (MG/L)	0.300 - 0.400	0.340	0.350		0.200 - 0.200	0.200	0.200		[redacted]
[redacted]	0.040 - 0.090	0.050	0.040		0.040 - 0.080	0.050	0.040		[redacted]
TOTAL N (MG/L)	0.320 - 0.460	0.390	0.370		0.220 - 0.260	0.250	0.220		[redacted]
CHLOPHYL A (UG/L)	3.9 - 8.1	5.7	5.5		4.3 - 9.0	5.2	5.4		[redacted]
SECCHI (METERS)	1.5 - 1.8	1.7	1.7		1.5 - 2.0	1.8	1.8		[redacted]

B. Biological characteristics:

1. Phytoplankton -

a. Grand Lake

Sampling Date	Dominant Genera	Algal Units per ml
08/26/75	1. Asterionella sp.	524
	2. Anabaena sp.	262
	3. Cryptomonas sp.	131
	4. Melosira sp.	87
	Total	1,003
10/10/75	1. Spondylosium sp.	339
	2. Cryptomonas sp.	136
	3. Melosira sp.	136
	4. Asterionella sp.	102
	5. Anabaena sp.	34
	Other genera	33
	Total	780

b. Shadow Mountain Lake

08/26/75	1. Aphanizomenon sp.	630
	2. Phormidium sp.	533
	3. Microcystis sp.	388
	4. Chroomonas sp.	291
	5. Nitzschia sp.	242
	Other genera	486
	Total	4,570
10/10/75	1. Melosira sp.	706
	2. Asterionella sp.	246
	3. Cryptomonas sp.	246
	4. Chroomonas (?) sp.	184
	5. Pennate diatoms	184
	Other genera	214
	Total	1,780

2. Chlorophyll a -

Sampling Date	Station Number	Chlorophyll a (ug/l)
08/26/75	Grand 1	5.5
	Grand 2	5.4
	S. M. 1	6.1
	S. M. 2	6.5
	S. M. 3	3.9
10/10/75	Grand 1	4.2
	Grand 2	4.0
	S. M. 1	4.3
	S. M. 2	6.0
	S. M. 3	5.4

C. Grand Lake Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

a. August sample -

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l-dry wt.)
Control	0.004	0.075	0.2
0.050 P	0.054	0.075	4.7
0.050 P + 1.0 N	0.054	1.075	6.3
1.0 N	0.004	1.075	0.2

b. October sample -

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l-dry wt.)
Control	0.005	0.085	0.4
0.050 P	0.055	0.085	3.0
0.050 P + 1.0 N	0.055	1.085	7.9
1.0 N	0.005	1.085	0.3

2. Discussion -

The control yields of the assay alga, Selenastrum capricornutum, indicate that the potential primary productivity

of Grand Lake was moderate at the times the samples were collected. Also, the significant increases in yields with the addition of phosphorus alone indicate the lake was phosphorus limited at those times. Note that the addition of nitrogen alone resulted in yields no greater than those of the controls.

The lake data also indicate phosphorus limitation. The mean inorganic nitrogen/orthophosphorus ratios were 16/1 or greater at all sampling stations and times.

Due to significant changes in nutrients in the samples during shipment from the field to the laboratory, the assay results for Shadow Mountain Lake are not considered representative of conditions in the lake at the sampling times. The lake data indicate a combination of limiting nutrients. Following is a tabulation of the mean N/P ratios at the sampling stations and times with the indicated limiting nutrient in parentheses.

Station	08/25/75	10/10/75
1	16/1 (P)	11/1 (N)
2	13/1 (N-P)	13/1 (N-P)
3	27/1 (P)	29/1 (P)

IV. NUTRIENT LOADINGS
(See Appendix E for data)

For the determination of nutrient loadings, the Colorado National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page v), except for the high runoff months of June and July when two samples were collected. Sampling was begun in September, 1974, and was completed in August, 1975.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Colorado District Office of the U.S. Geological Survey for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries were calculated using mean annual concentrations and mean annual flows. Nutrient loads for the Alva B. Adams Aqueduct were calculated using the mean nutrient concentrations at Grand Lake sampling station 1 and the mean annual aqueduct flow.

Nutrient loads for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated using the mean concentrations in Unnamed Creek at station F-1 of Shadow Mountain Lake and the mean annual ZZ flow.

The operator of the Grand Lake Sanitation District wastewater treatment plant provided monthly effluent samples and corresponding flow data.

A. Waste Sources:

1. Known municipal[†] -

Name	Pop. Served	Treatment	Mean Flow (m^3/d)	Receiving Water
Grand Lake SD	1,475[††]	act. sludge	1,356.9	Shadow Mtn. Lake

2. Known industrial - None

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	kg P/yr	% of total
a. Tributaries (non-point load) -		
North Inlet	1,255	12.1
Echo Creek	500	4.8
Colorado River	2,365	22.7
Granby Pump Canal	5,070	48.7
b. Minor tributaries & immediate drainage (non-point load) -	135	1.3
c. Known municipal STP's -		
Grand Lake SD	920	8.8
d. Septic tanks* -	45	0.4
e. Known industrial - None	-	-
f. Direct precipitation** -	130	1.2
Total	10,420	100.0

2. Outputs -

Lake outlets -	Adams Aqueduct	3,665
	Colorado River	2,295
	total	5,960

3. Net annual P accumulation - 4,440 kg

† Treatment plant questionnaire.
†† Population equivalent based on 300 winter residents and a maximum of 5000 summer residents.
* Estimate based on 161 lakeshore dwellings; see Working Paper No. 175.
** See Working Paper No. 175.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/yr	% of total
a. Tributaries (non-point load) -		
North Inlet	42,235	10.5
Echo Creek	20,950	5.2
Colorado River	83,255	20.7
Granby Pump Canal	239,920	59.5
b. Minor tributaries & immediate drainage (non-point load) -	3,186	0.8
c. Known municipal STP's -		
Grand Lake SD	3,695	0.9
d. Septic tanks* -	1,719	0.4
e. Known industrial - None	-	-
f. Direct precipitation** -	8,130	2.0
Total	402,685	100.0

2. Outputs -

Lake outlets -	Adams Aqueduct	78,815
	Colorado River	120,665
Total		199,480

3. Net annual N accumulation - 203,205 kg.

D. Non-point Nutrient Export by Subdrainage Area:

Tributary	kg P/km²/yr	kg N/km²/yr
North Inlet	11	355
Echo Creek	2	290
Colorado River	9	315

* Estimate based on 161 lakeshore dwellings; see Working Paper No. 175.
** See Working Paper No. 175.

E. Mean Nutrient Concentrations in Ungaged Streams:

Tributary	Mean Total P Conc. (mg/l)	Mean Total N Conc. (mg/l)
Little Columbine Creek	0.032	0.170
Onahu Creek	0.022	0.667
Unnamed Creek	0.019	0.461

F. Yearly Loads:

In the following table, the existing phosphorus loadings are compared to those proposed by Vollenweider (Vollenweider and Dillon, 1974). Essentially, his "dangerous" loading is one at which the receiving water would become eutrophic or remain eutrophic; his "permissible" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic loading would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with short hydraulic retention times.

	Total Phosphorus		Total Nitrogen	
	Total	Accumulated	Total	Accumulated
grams/m²/yr	1.38	0.59	53.5	27.0

Vollenweider phosphorus loadings (g/m²/yr) based on combined mean depth* and mean hydraulic retention time of Grand Lake and Shadow Mountain Lake:

"Dangerous" (eutrophic loading)	1.40
"Permissible" (oligotrophic loading)	0.70

* Mean depth of the lakes calculated by adding both volumes and both areas and dividing the combined volume by the combined area.

V. LITERATURE REVIEWED

Anderson, Dennis P., 1974. Personal communication (lake morphometry). CO Dept. of Health, Denver.

Nelson, Wesley C., 1971. Comparative limnology of Colorado--Big Thompson Project reservoirs and lakes. CO Dept. of Nat. Res., Fort Collins.

Vollenweider, R. A., and P. J. Dillon, 1974. The application of the phosphorus loading concept to eutrophication research. Natl. Res. Council of Canada Publ. No. 13690, Canada Centre for Inland Waters, Burlington, Ontario.

VI. APPENDICES

APPENDIX A

LAKE RANKINGS

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

APPENDIX B

CONVERSION FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107×10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX C

TRIBUTARY FLOW DATA

[redacted]

[illegible]

[illegible]

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

APPENDIX D

PHYSICAL and CHEMICAL DATA

[redacted]

[redacted]

[redacted]													
[redacted]													
[redacted]													
[redacted]													

[illegible]

| | | |

[illegible]

[illegible]
[illegible]
[illegible]
[illegible]

[illegible]
[illegible]

DATE	TIME	DEPTH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FROM	TO											
	DAY	FEET										
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

DATE	TIME	DEPTH	[illegible]	[illegible]	[illegible]
FROM	TO				
	DAY	FEET	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]		

[illegible]
[illegible]

APPENDIX E

TRIBUTARY AND WASTEWATER TREATMENT PLANT DATA

[illegible]

[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]
[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]
[illegible]
[illegible]

[illegible]

DATE	TIME	DEPTH FEET	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7-[illegible]-79	12	45	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7-[illegible]-79	13	10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7-[illegible]-79	13	30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7-[illegible]-79	10	20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7-[illegible]-79	10	35	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7-[illegible]-79	10	30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7-[illegible]-79	11	40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7-[illegible]-79	17	10	[illegible]	[illegible]	[illegible]		[illegible]
7-[illegible]-79	11	15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7-[illegible]-79	17	35	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7-[illegible]-79	14	45	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7-[illegible]-79	10	30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7-[illegible]-79	13	35	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

* VALUE [illegible]
LESS THAN INDICATED

[illegible]

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]							
[illegible]							
[illegible]							
[illegible]							
[illegible]							
[illegible]							
[illegible]							
[illegible]							
[illegible]							
[illegible]							
[illegible]							
[illegible]							
[illegible]							
[illegible]							

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

[illegible]

[illegible]									
[illegible]									
[illegible]									
[illegible]									